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ScienceDirect
Biosurface and Biotribology 2 (2016) 81–85
www.elsevier.com/locate/bsbt

Ig Nobel Prize-winning episode: Trip from a slip on a banana peel to the mysterious world of mucus

K. Mabuchi[a,*], R. Sakai[a,b], M. Honna[b], M. Ujihira[a,b]

[a]School of Allied Health Sciences, Kitasato University, 1-15-1 Kitasato, Minami-ku, Sagamihara, Kanagawa 252-0373, Japan
[b]Graduate School of Medical Sciences, Kitasato University, 1-15-1 Kitasato, Minami-ku, Sagamihara, Kanagawa 252-0373, Japan

Received 20 November 2015; received in revised form 19 July 2016; accepted 26 August 2016

Abstract

Slip on a banana peel is not only a gag seed but also a genuinely tribological phenomenon. We measured the frictional coefficient under banana skin on floor material. The measured frictional coefficient was much lower than the value on common materials and similar one on well lubricated surfaces. Some deductions on mystery of organics were leaded from the similarity of gel function in banana peels and in articular joints. Every polymers are only synthesized by organisms. Furthermore, viscous materials are only formed by organic substances.

Keywords: Banana skin; Frictional coefficient; Follicle gel lubrication; Mystery of organics

1. Introduction

I became interested in analyzing the movement of stepping and slipping on a banana peel – a comic routine known throughout the world, from the viewpoint of friction, and conducted extensive experiments to examine its slipperiness. I examined the mechanism related to its slipperiness: when a banana peel is stepped on, a type of mucosal fluid is secreted as a lubricant. I also discussed the roles of mucus, which is generated only by organisms.

2. The road lead to a banana peel

In 1972, I chose "lubrication in joint prostheses" as the theme of my graduation thesis despite other engineering students' curious eyes. The literature that I have read first was a paper written by McCutchen (1962), which explained the slipperiness of synovial joints using the theory of weeping lubrication [1]. My encounter with this paper helped me conduct my research that received the Ig Nobel Prize 40 years later [2].

Weeping lubrication is a mechanism in which a fluid excreted from articular cartilages forms a lubricating film to increase the smoothness between the joints. I had been thinking that the mechanism of weeping lubrication resembled that of slipping on a banana peel. When writing books or papers, I chose the peels of bananas, from among many other things available in our daily lives, to explain the mechanism of weeping lubrication [3]. At that time, I thought that the results of experiments to examine the slippery characteristic of banana peels had already been published as it was a fact known to everyone. However, there were no scientific papers on the slippery characteristic of banana peels, although some previous studies were related to the peels: a practical example of the use of banana peels for the launch of ships to replace grease [4] and an ordinance issued by Cambridge City that slippery waste including banana peels must not be left on the streets [5].

Approximately 10 years ago, I became determined to analyze the characteristics of banana peels, because I thought I was responsible, as a researcher involved in bio-tribology, for conducting research that had not yet been implemented.

*Corresponding author.
E-mail address: km@kitasato-u.ac.jp (K. Mabuchi).
Peer review under responsibility of Southwest Jiaotong University.

http://dx.doi.org/10.1016/j.bsbt.2016.08.001
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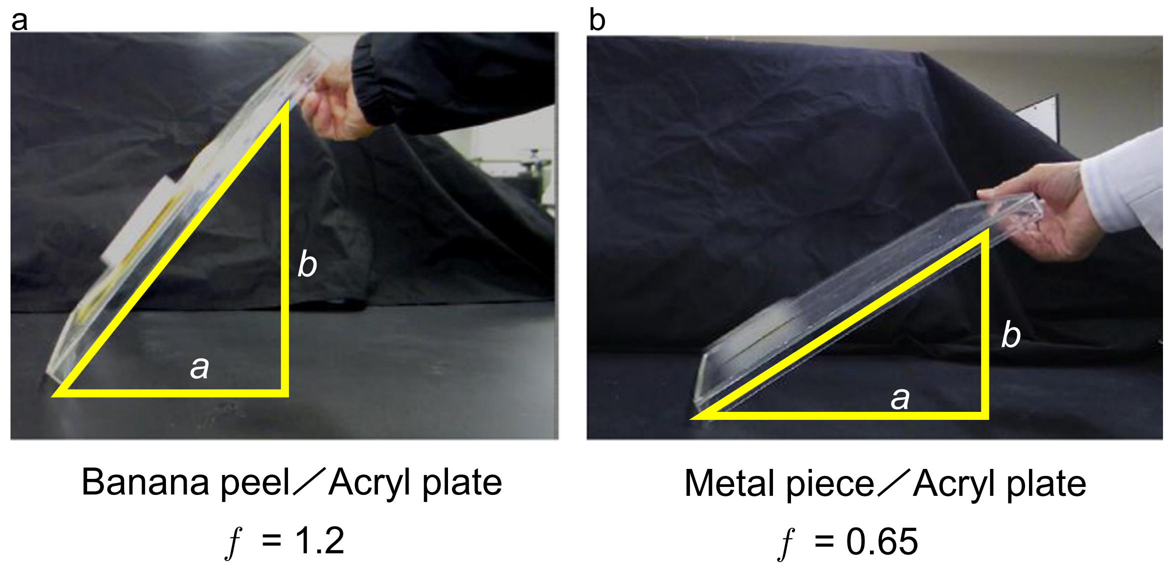

Fig. 1. The result of measurement of the angle of friction.

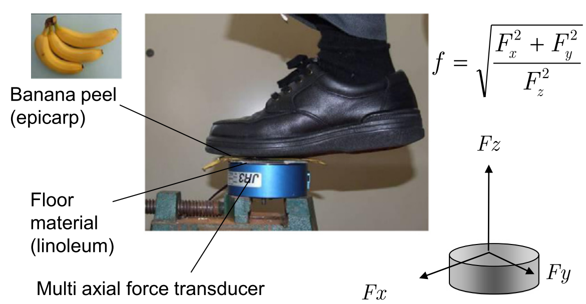

Fig. 2. A scene of friction measurement using a multiaxial load transducer. A banana peel placed on the sensors was stepped on.

3. Measurement of friction under a banana peel

If something is slippery, it means that its frictional coefficient is low. Therefore, you can objectively determine the difference in the slipperiness of two objects by comparing their frictional coefficients. I thought that I would easily find the answer by conducting an elementary physical experiment using banana peels, which were available to anyone.

In an experiment, I placed a banana peel on a slope, and determined the angle of the slope at which the peel started to slide down it – the angle of friction. The tangent of the angle of friction is the frictional coefficient. To my surprise, the measured angle of friction was greater than 45° (Fig. 1). In other words, the frictional coefficient was 1.0 or higher – a significantly large value. Considering that the frictional coefficient between the surface of a standard-type floor and shoe sole is approximately 0.4, it is reasonable to assume that an accident of slipping on a banana peel can rarely occur. Therefore, I had to reproduce the conditions required for people to slip on a banana peel, as explained in the preceding paragraphs.

To measure the frictional coefficient of a banana peel sliding on the floor, a person needed to step on it. However, stepping on a banana peel placed on a slope was dangerous and difficult.

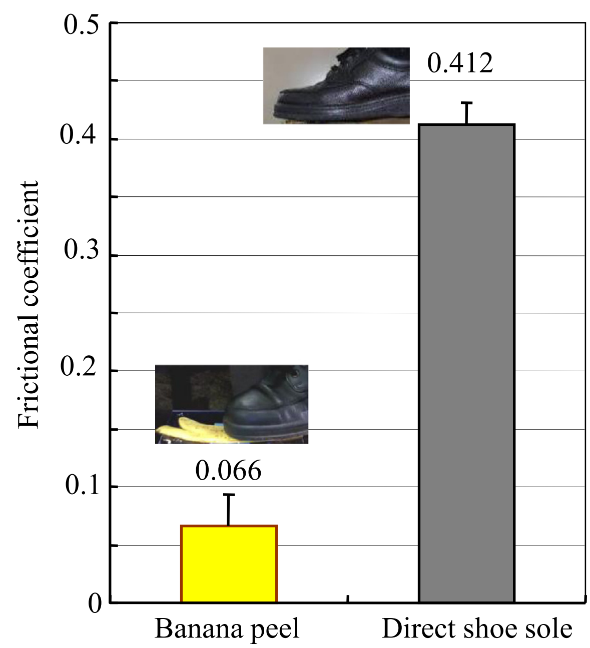

Fig. 3. Frictional coefficients under a banana peel [2].

Fortunately, there were a number of friction measurement devices introduced to examine the joint function in my laboratory. I thought that I would be able to measure the frictional coefficient of a banana peel while being stepped on, using those devices. I conducted the following experiment as presented in Fig. 2: I stepped on a banana peel placed on a floor board fixed on multiaxial load sensors, and measured both the normal and frictional forces.

4. Frictional coefficient under a banana peel

Whereas the frictional coefficient between the shoe sole and floor board was 0.412, the coefficient between the shoe sole and banana peel was 0.066 ($n=60$, SD$=0.028$), as shown in Fig. 3. In other words, the banana peel was six times as slippery. The frictional coefficient of the banana peel was as low as that of the surface of a ski on snow and ice skate blade on ice [6] (Fig. 4). These results supported the assumption that a banana peel is slippery when it is stepped on.

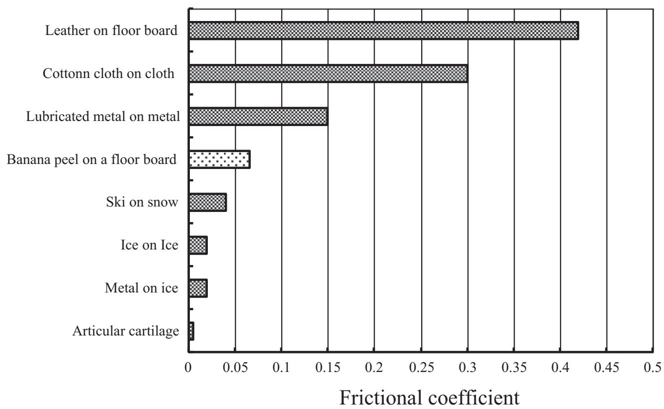

Fig. 4. Frictional coefficients under various materials [3,6].

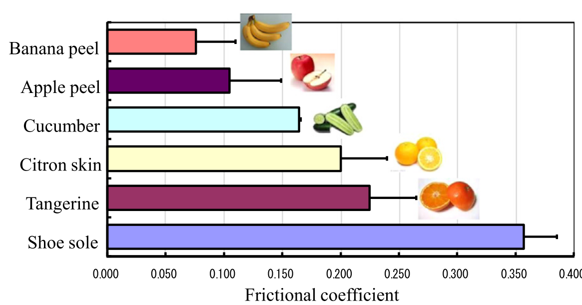

Fig. 5. Frictional coefficients under the peels of fruits and the floor board [2].

The study was adequately novel because it explained the slipperiness of banana peels using objective data. For the further discussions, I conducted additional experiments. The results suggested that: the frictional coefficient of the internal surface was twice as high, dried banana peels were not slippery, and the peels of bananas were more slippery than those of oranges and apples. The mechanisms to improve slipperiness, or lubrication, were deduced from these results.

Since banana peels became solidified and less slippery when they were dried, water, rather than oil, presumably played the primary role in increasing the slipperiness of banana peels. Although the water content of apple peels was higher than that of banana peels, the frictional coefficient of apple peels was higher (Fig. 5).

The viscosity of a fluid excreted from a banana peel was higher, presumably because bananas contained larger amounts of constituents related to sweetness than apples.

Whereas the internal surfaces of fresh banana peels are white and smooth, they turn brown when they are stepped on (Fig. 6). I conducted a microscopic observation to thoroughly examine the difference, and revealed that white vesicles on the fresh surface turn into viscous fluid covering the surface of the peels when they are stepped on (Fig. 6).

As a conclusion of the study, I explained the important mechanism of follicle gel lubrication: when small cells on the internal surface of banana peels are stepped on and disrupted, mucus is excreted and forms a lubrication film (Fig. 7). I subsequently finished writing the world's first paper on the slipperiness of banana peels [2].

5. The mystery of mucus

I explained the slipperiness of banana peels using mucus, and the explanation was easily accepted. However, since

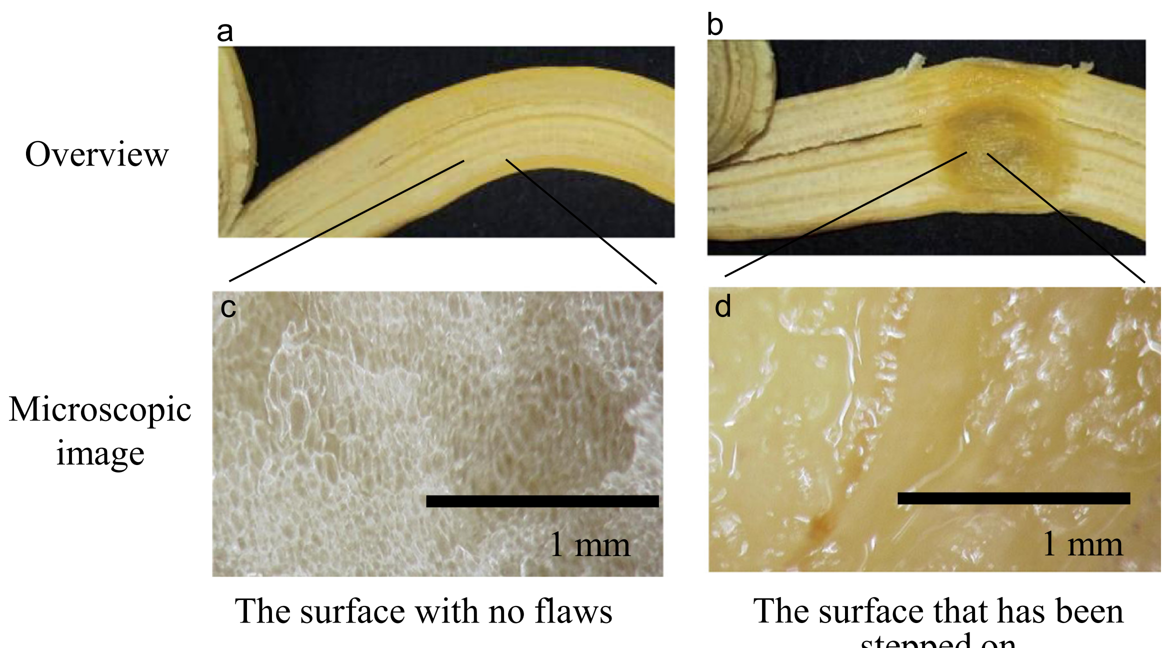

Fig. 6. The change in a banana peel. Stereomicroscopic images at the bottom [2].

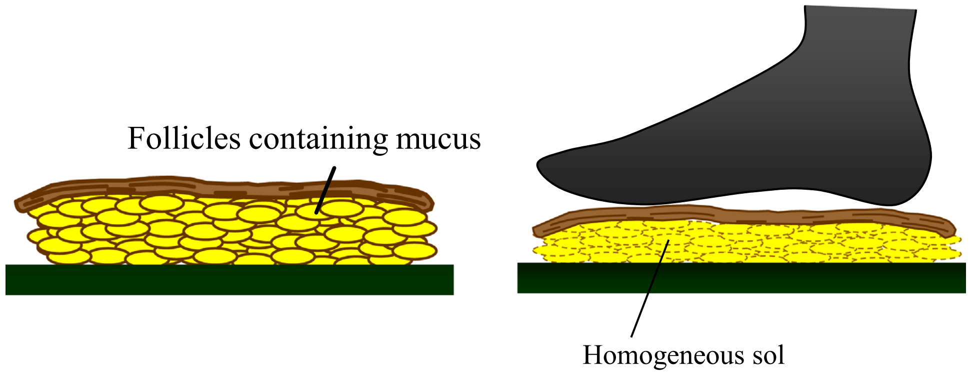

Fig. 7. Disruption of follicles when they are stepped on [2].

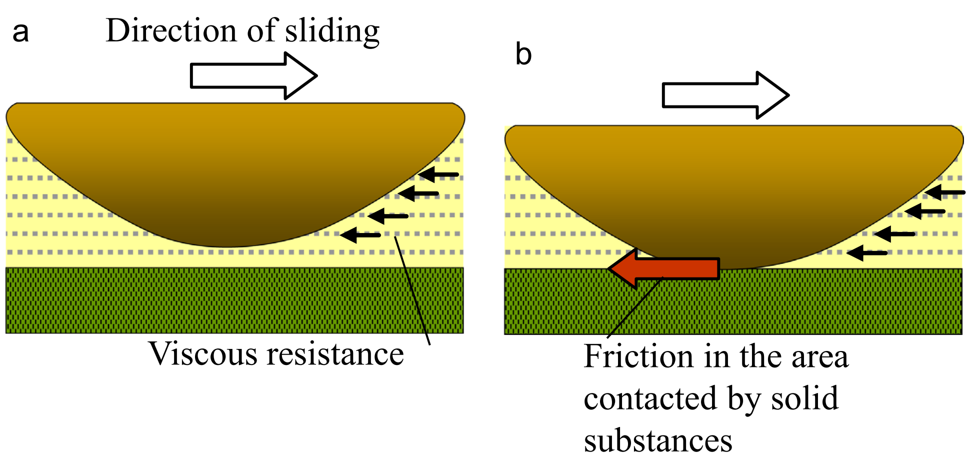

Fig. 8. States of fluid lubrication and being contacted by a solid substance.

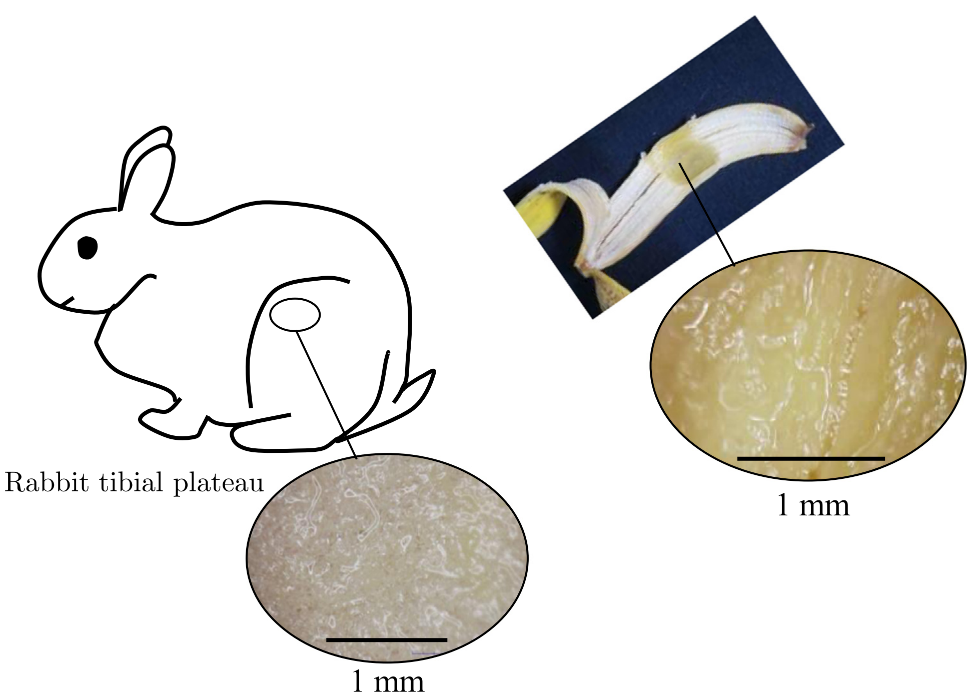

Fig. 9. Mucus on a cartilage of a rabbit tibia and on a banana peel.

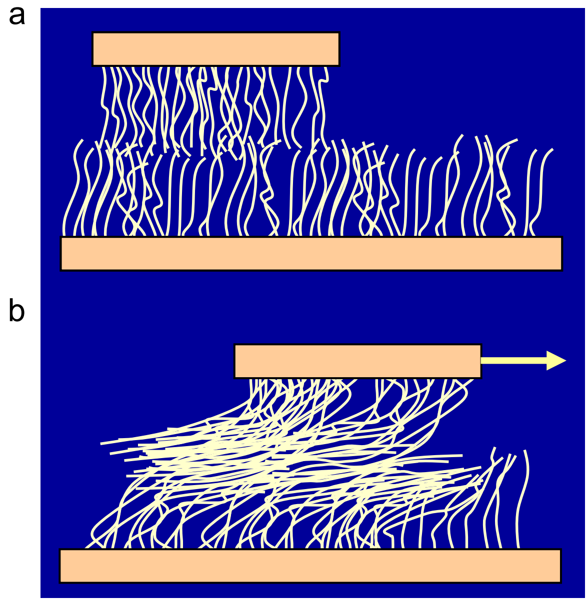

Fig. 10. Mucopolysaccharide fibers parallelly orientated each other with the sliding motion of the planes.

viscosity is a characteristic that interferes with the flow of fluid, it should be frictional resistance (Fig. 8). Then, why is the surface of banana peels slippery? The viscosity of lubricating fluid actually prevents it from flowing out of the frictional surface, and, as a result, the force of friction will be significantly smaller than the force generated from contact between two solids (Fig. 8). This mechanism is referred to as squeeze film lubrication, and the higher the viscosity of lubricating fluid, the greater the effect.

After receiving the Ig Nobel Prize, I looked back on the initiation of my research on banana peels, and discussed the association between joint lubrication and the slipperiness of banana peels again. I recognized the fact that mucus plays the primary role in both of them (Fig. 9). The result is an achievement that I accomplished through the award-winning study.

It is difficult to accurately identify the composition of the constituents of mucus excreted from banana peels, because it is difficult to identify the structure of polymer molecules and analyze substances in a wet state. The mucus is not derived from proteins because it does not smell bad even if it is left for a while. It is presumably derived from sugar because the viscosity of mucus from sweet fruits is significantly higher. Common mucus excreted from plants is derived from mannan, fucoidan, and other polysaccharides. Hyaluronic acid, constituent of joint fluid, is also mucopolysaccharide.

In the bodies of animals, the surfaces of the heart and lungs and the surrounding tissues are in a frictional motion throughout the day. The smoothness of the surfaces of these organs is also essential to life, and mucus supports this smoothness [7,8].

Mucopolysaccharide forms fiber framework based on solid surfaces. When the surfaces slide, the fibers parallelly orientate each other, as shown in Fig. 10. Smooth sliding can be realized with the smooth sliding of the fiber sides.

All polymer molecules that support viscosity are organic substances, which are generated by genes. However, modern technology has not succeeded in creating organic substances without relying on organisms. Furthermore, organic substances are essential for the generation of polymer molecules. All fluids with a high viscosity are derived from organisms, after all. Lubricating oil for industrial use, which is used for machines and equipment, is no exception. This suggests that all lubrication technologies to decrease the frictional coefficient and increase the slipperiness rely on the genetic functions of organisms, and that our modern technologies are immature.

Acknowledgments

This work was supported by JSPS KAKENHI Grant Number JP (C) 26420083.

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